Immune computing: intelligent methodology and its applications in bioengineering and computational mechanics

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Nature inspired computing has proved to be useful in various application areas. Evolutionary methods, neural networks, swarm intelligence and many other approaches have been applied to many technical and engineering problems, such as optimization, learning, data analysis, knowledge engineering and many others. Some of these methods perform better in the given application areas and some work better in others. However, it can hardly be assumed that there exists a problem domain in which nature inspired techniques are not employed, at least as a part of the proposed solution. After decades of development, biologically inspired methods are well established and appreciated tools. On the other hand, many novel approaches arise to solve problems in innovative ways, hopefully more effectively. One of such novel areas is the field of *Artificial Immune Systems (AIS)* [1]. The question arises as to what AIS can offer as problem solving techniques and whether the paradigms proposed by AIS researchers are in fact novel. The aim of this paper is to provide a set of carefully selected problems connected with the current research directions of *Immune Computing*.

Immune system, especially this of vertebrates, is a very complicated system of interacting cells, organs and mechanisms, whose purpose is to protect the host body against any danger, either exterior or internal. To achieve that goal the immune system has to decide not only about what is not part of the host but also what can cause a damage. This is a very difficult task, as not all that comes from outside is dangerous. On the other hand, autoimmune diseases are examples of internal threats. To protect the host against all such dangers is not an easy task, especially in a changing environment. It is obvious that the immune system has to develop some sense of self, i.e., the sense of what is part of the host. How the immune system achieves this is hard to explain, as the host body changes its functioning and structure over time. Nonetheless, the immune system is able to perform its task effectively. To deal with such difficult task the immune system needs the ability to learn new threats, to remember previous experiences and to develop specialized responses to different pathogens. Taking a closer look at all these features one can state that the immune system can be considered as a cognitive system. For that reason the immune system gained an interest of computational sciences.

Given all the complexity of functioning of the immune system, it is necessary to extract higher level paradigms which could serve as the basis of constructing computational models and algorithmic solutions. The most important paradigms in the filed of Artificial Immune Systems are *Clonal Selection* (CS), *Immune Network Theory* (IMT), *Negative Selection* (NS) and recently emerged *Danger Theory* (DT).

The question is whether AIS can offer anything really new and/or useful. Clonal Selection can seem to be another exemplification of evolutionary approach to problem solving. The fact of existing of immune networks in biological immune systems is questioned by biologists. Negative Selection appears to be truly novel approach, but one could ask whether it is enough to invest time and resources to develop AIS. In the first examinations of the immune ideas, the researchers developed several algorithmic solutions based on immune paradigms, often separately. Clonal Selection and Immune Network Theory have been applied to optimization, data analysis or clustering. Negative Selection has been applied to computer security, anomaly or fault detection. Many of the proposed algorithms have successfully dealt with the tasks appointed to them. However, their usefulness according to their robustness and scalability has been under dispute when compared to other well established computational methods.

Possibility of a coupling immune computing with the finite element method in solving several 2-D and 3-D optimization and inverse problems will be considered. Applications to bioengineering problems as feature selection and classification of ECG signals will be also presented.

The paper contains also a proposal of a novel Clonal Selection algorithm, *Immune K-Means*, and its application data analysis and classification. Possible ways of combining *Immune K-Means* with Negative Selection algorithms, particularly with *V-Detector*, are presented. Building such higher level AIS that include several immunological concepts, seems to be reasonable and provide new possibilities to construct well functioning algorithms. Immune K-Means algorithm can also be perceived as an example of combining immune paradigms with other well established methods in computational science. Combining Clonal Selection principle with k-means clustering algorithm results in an interesting hybrid methodology.

The broad application areas and the new ideas proposed, show the vitality of the still young research field of Immune Computing in intelligent problem solving techniques.

References

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2. Wierzchoń S.T., *Artificial Immune Systems*. Theory and Applications. Exit, Warsaw 2001 (in Polish).